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101-SCBMA-Opinions
Bicycle Steerer Tube
Connections-Lockwood
v. Pacific Bicycle, *et al*
August 20, 2002

Mr. Michael P. Smith, Esq.
Salsbury Clements Bekman
Marder & Adkins, L. L. C.
300 West Pratt Street Suite 450
Baltimore, MD 21201

Re: Lockwood v. Pacific Cycle, *et al* WMN-02-2068 (Steerer Tube Connection)

Dear Mr. Smith,

After examining the Pacific Cycle manufactured bicycle in question at Mr. John Schubert's office earlier this year, I have the following technical opinions concerning the mechanical reliability and safety of the steel steerer tube connection:

1. The thin-walled, hollow-steel, steerer tube was mechanically press-fit and possibly thermally interference fit into the steerer tube fork crown. (Thermal expansion coefficients and elastic moduli of both steel and aluminum alloys are attached.) R. W. Hinton saw no evidence of either a welded joint or a chemically bonded joint.

2. The fork crown into which the steerer tube was inserted appears to be made of a nonferrous (non-steel) alloy such as, an aluminum alloy. The elastic gripping force of an aluminum alloy fork crown provides one-third the elastic gripping force of a steel fork crown of the same size.

PLAINTIFF'S EXHIBIT 2

3. In addition, an even weaker gripping force between the thin-walled hollow steel steerer tube, and the nonferrous alloy fork crown would be expected because the thin hollow tube yields (elastically) in compression. (Mechanical and physical properties of carbon steel and aluminum alloys are attached.)

4. No safety device or retightening device was found on the steerer tube fork crown to prevent the steerer tube of the bicycle from pulling out when the tube-to-fork crown mechanical bond becomes loose and the fork crown is worn from normal use. (A graph is attached that shows wear resistance of nonferrous alloys relative to American Iron and Steel Industry [AISI] 1010 sheet steel.)

In summary, the press-fit and /or the thermal interference fit between the thin-walled hollow steerer tube and the nonferrous (aluminum alloy) fork crown of the bicycle in question is inadequate, unsafe, and cannot be retightened or inspected.

As requested earlier of the manufacturer, dimensions (engineering drawings) and manufacturing specifications including the specified materials of construction would be required to further analyze the intended engineering and safety of this bicycle. In addition, a desired destructive test to determine the hardness and composition of the steerer tube and fork crown would enhance and make specific the engineering analyses contained herein.

The enclosed R. W. Hinton engineering analyses and resulting opinions are expressed to a reasonable degree of engineering certainty. If more information becomes available, R. W. Hinton will supplement this preliminary report.

Sincerely yours,

Robert W. Hinton

Robert W. Hinton, Ph. D., PE

Attachments

Table A-7 PHYSICAL CONSTANTS OF MATERIALS

Material	Modulus of elasticity, E		Modulus of rigidity, G		Poisson's ratio	Unit weight, w		
	Mpsi	GPa	Mpsi	GPa		lb/in^3	lb/ft^3	kN/m^3
Aluminum (all alloys)	10.3	71.0	3.80	26.2	0.334	0.098	169	26.6
Beryllium copper	18.0	124.0	7.0	48.3	0.285	0.297	513	80.6
Brass	15.4	106.0	5.82	40.1	0.324	0.309	534	83.8
Carbon steel	30.0	207.0	11.5	79.3	0.292	0.282	487	76.5
Cast iron, gray	14.5	100.0	6.0	41.4	0.211	0.260	450	70.6
Copper	17.2	119.0	6.49	44.7	0.326	0.322	556	87.3
Douglas fir	1.6	11.0	0.6	4.1	0.33	0.016	28	4.3
Glass	6.7	46.2	2.7	18.6	0.245	0.094	162	25.4
Inconel	31.0	214.0	11.0	75.8	0.290	0.307	530	83.3
Lead	5.3	36.5	1.9	13.1	0.425	0.411	710	111.5
Magnesium	6.5	44.8	2.4	16.5	0.350	0.065	112	17.6
Molybdenum	48.0	331.0	17.0	117.0	0.307	0.368	636	100.0
Monel metal	26.0	179.0	9.5	65.5	0.320	0.319	551	86.6
Nickel silver	18.5	127.0	7.0	48.3	0.322	0.316	546	85.8
Nickel steel	30.0	207.0	11.5	79.3	0.291	0.280	484	76.0
Phosphor bronze	16.1	111.0	6.0	41.4	0.349	0.295	510	80.1
Stainless steel (18-8)	27.6	190.0	10.6	73.1	0.305	0.280	484	76.0

J.E. Shigley
Mechanical Engineering Design
3rd Ed. McGraw Hill 1977

ASM Metals Handbook
reprint 1958

Linear Thermal Expansions of Metals and Alloys

THE NUMBERS in this table have been collected from the numerous articles and data sheets that record in detail the properties of metals in this Handbook. The values are collected here for the reader's convenience in making general comparisons. For more specific information concerning the expansion of SAE steels, the table on page 309 should be consulted. Additional data for nonferrous metals and alloys will be found under item D6 in the data sheets. Values given here are for as-cast, as-wrought or as-annealed material. The effects of thermal treatment, temperature range and other factors are indicated in the various places mentioned above.

Aluminum and Aluminum Alloys

	Metal	Temperature, deg Cent	Coefficient of Expansion per deg Cent
	Aluminum (99.95%)	20 to 100	$\times 10^{-6}$ 23.9
	Wrought		
2 S	99.0 Al	20 to 100	23.5
3 S	1.2 Mn	20 to 100	23.2
11 S	5.5 Cu, 0.5 Pb, 0.5 Bi	20 to 100	22.9
2417 14 S	4.4 Cu, 0.8 Si, 0.8 Mn, 0.4 Mg	20 to 100	22.5
17 S	4 Cu, 0.5 Mn, 0.5 Mg	20 to 100	23.0
2024 18 S	4 Cu, 2 Ni, 0.5 Mg	20 to 100	22.4
24 S	4.5 Cu, 1.5 Mg, 0.6 Mn	20 to 100	22.8
25 S	4.5 Cu, 0.8 Mn, 0.8 Si	20 to 100	22.8
32 S	12.5 Si, 1.0 Mg, 0.9 Cu, 0.9 Ni	20 to 100	19.4
A51 S	1.0 Si, 0.6 Mg, 0.25 Cr	20 to 100	23.1
53 S	2.5 Mg, 0.25 Cr	20 to 100	23.8
52 S	1.3 Mg, 0.7 Si, 0.25 Cr	20 to 100	22.9
56 S	5.2 Mg, 0.1 Mn, 0.1 Cr	20 to 100	24.3
61 S	1.0 Mg, 0.6 Si, 0.25 Cu, 0.25 Cr	20 to 100	23.5
7075 75 S	5.5 Zn, 2.5 Mg, 1.5 Cu	20 to 100	23.2
	Cast		
43	5 Si	20 to 100	22.0
108	4 Cu, 3 Si	20 to 100	22.0
113	7 Cu, 2 Si, 1.7 Zn	20 to 100	22.0
122	10 Cu, 0.2 Mg	20 to 100	22.0
142	4 Cu, 2 Ni, 1.5 Mg	20 to 100	22.5
195	4.5 Cu	20 to 100	23.0
214	3.8 Mg	20 to 100	24.0
220	10 Mg	20 to 100	24.5
355	5 Si, 1.3 Cu, 0.5 Mg	20 to 100	22.0
356	7 Si, 0.3 Mg	20 to 100	21.5
A108	5.5 Si, 4.5 Cu	20 to 100	21.5
A132	12 Si, 2.5 Ni, 1.2 Mg, 0.8 Cu	20 to 100	19.0
B195	4.5 Cu, 2.5 Si	20 to 100	22.0
750	6.5 Si, 1 Cu, 1 Ni	20 to 100	23.1
13	12 Si	20 to 100	20.0
85	5 Si, 4 Cu	20 to 100	21.0
218	8 Mg	20 to 100	23.7
360	9.5 Si, 0.5 Mg	20 to 100	19.5

Copper and Copper Alloys(a)

Metal	Temperature, deg Cent	Coefficient of Expansion per deg Cent
Pure Copper	20 to 100	16.5
Electrolytic Tough Pitch Copper	20 to 300	17.7
Deoxidized Copper	20 to 300	17.7
Wrought		
Gilding Metal, 95%	20 to 300	18.1
Commercial Bronze, 90%	20 to 300	[illegible]
Red Brass, 85%	20 to 300	18.7
Low Brass, 80%	20 to 300	19.1
Cartridge Brass, 70%	20 to 300	19.9
Muntz Metal	20 to 300	20.8
Leaded Commercial Bronze	20 to 300	18.4
Low-Leaded Brass	20 to 300	20.2
High-Leaded Brass	20 to 300	20.3
Free-Cutting Brass	20 to 300	20.5
Leaded Muntz Metal	20 to 300	20.8
Forging Brass	20 to 300	20.7
Architectural Bronze	20 to 300	20.9
Admiralty Metal	20 to 300	20.2
Naval Brass	20 to 300	21.2
Manganese Bronze	20 to 300	21.2
Aluminum Brass	20 to 300	18.5
Phosphor Bronze, 1.25% (E)	20 to 300	17.8
Phosphor Bronze, 5% (A)	20 to 300	17.8
Phosphor Bronze, 8% (C)	20 to 300	18.2
Phosphor Bronze, 10% (D)	20 to 300	18.4
Cupro-Nickel, 30%	20 to 300	16.2
Nickel Silver, 18% (A)	20 to 300	16.2
Nickel Silver, 18% (B)	20 to 300	16.7
Silicon Bronze, Type A	20 to 300	18.0
Silicon Bronze, Type B	20 to 300	17.9
Aluminum Bronze, 8%	20 to 300 — 10.1×10^{-6}	18.2
Beryllium Copper	20 to 100	16.6
Cast		
Leaded Tin Bronze	21 to 260	18.5
Leaded Tin Bearing Bronze	21 to 177	18.0
Ounce Metal	21 to 204	19.1
Leaded Yellow Brass	21 to 260	21.6
High Strength Yellow Brass	21 to 260	19.8
Leaded Manganese Bronze	21 to 204	20.5
Aluminum Bronze (89-1-10)	21 to 260	17.1

Iron and Iron Alloys

See also page 309

Metal	Temperature, deg Cent	Coefficient of Expansion per deg Cent
Pure Iron	20	$\times 10^{-6}$ 11.7
Fe-C Alloys 0.06% C	20 to 100	11.7 — 6.5×10^{-6}/°F
0.22% C	20 to 100	11.7
0.40% C	20 to 100	11.3
Low alloy steels 0.56% C	20 to 100	11.0
1.08% C	20 to 100	10.8
1.45% C	20 to 100	10.1
1.97% C	20 to 100	9.9
2.24% C	20 to 100	9.6
3.66% C	20 to 100	8.6
Invar Fe, 36 Ni	r t	0 to 2
13 Mn, 1.2 C	r t	18
13 Cr, 0.35 C	20 to 100	10.0
12.3 Cr, 0.4 Ni, 0.09 C	20 to 100	9.8 — 5.4×10^{-6}/°F
17.7 Cr, 9.6 Ni, 0.06 C	20 to 100 — 9.2×10^{-6}	16.5
18 W, 4 Cr, 1 V	0 to 100	11.2 — 6.2×10^{-6}/°F
Gray Cast Iron	0 to 100	10.5
Malleable Iron	....	12

Lead and Lead Alloys

Metal	Temperature, deg Cent	Coefficient of Expansion per deg Cent
Pure Lead (99.73%)	17 to 100	29.3
1% Antimonial Lead	20 to 100	28.8
Hard Lead 96 Pb, 4 Sb	20 to 100	27.8
Hard Lead 94 Pb, 6 Sb	20 to 100	27.2
8% Antimonial Lead 92 Pb, 8 Sb	20 to 100	26.7
Grid Metal 91 Pb, 9 Sb	....	26.4
Lead-Base Babbitt 80 Pb, 15 Sb, 5 Sn	20 to 100	24.0
Lead-Base Babbitt 75 Pb, 15 Sb, 10 Sn	20 to 100	19.6
Tin-Lead Solder 95 Pb, 5 Sn	15 to 110	28.7
Tin-Lead Solder 80 Pb, 20 Sn	15 to 110	26.5
Half and Half 50 Pb, 50 Sn	15 to 110	23.4

Magnesium and Magnesium Alloys(d)

Metal	Temperature, deg Cent	Coefficient of Expansion per deg Cent
Pure Magnesium (99.80%)(d)	40	26

Nickel and Nickel Alloys

Metal	Temperature, deg Cent	Coefficient of Expansion per deg Cent
Pure Nickel (99.95 Ni + Co)	0 to 100	13.3
"A" Nickel (99.4 Ni + Co)	25 to 100	13.3
Cast Nickel 1.5 Si, 0.5 Mn, 0.5 C	25 to 100	13.0
"Z" Nickel 4.5 Al	0 to 100	13.0
Monel 30 Cu, 1.4 Fe, 1.0 Mn, 0.15 C	0 to 100	14.0
"K" Monel 29 Cu, 3 Al	25 to 100	14.0
"S" Monel 30 Cu, 4 Si, 2 Fe	21 to 100	12.2
Cast Monel 32 Cu, 1.6 Si, 0.2 C	25 to 100	[illegible]
Hastelloy A 20 Mo, 20 Fe	0 to 100	11.0
Hastelloy B 30 Mo, 5 Fe	0 to 100	10.0
Hastelloy C 17 Mo, 15 Cr, 5 W, 5 Fe	0 to 100	11.3
Hastelloy D 8 to 11 Si, 3 Cu	0 to 100	11.0
Inconel 14 Cr, 6 Fe	0 to 100	11.5
Chromel A 20 Cr	70 to 1000	17.6
Nichrome 24 Fe, 16 Cr	20 to 1000	17.0
Chromax 50 Fe, 15 Cr	20 to 500	15.8
Constantan 45 Ni	20 to 1000	18.8

Tin and Tin Alloys

Metal	Temperature, deg Cent	Coefficient of Expansion per deg Cent
Pure Tin	0 to 100	23.0
Soft Solder 70 Sn, 30 Pb	15 to 110	21.6
Eutectic Solder 63 Sn, 37 Pb	15 to 100	24.7

Zinc and Zinc Alloys

Metal	Temperature, deg Cent	Coefficient of Expansion per deg Cent
Pure Zinc	20 to 250	39.7
Zamak 3 4 Al, 0.04 Mg	20 to 100	27.4
Zamak 5 4 Al, 1 Cu, 0.04 Mg	20 to 100	27.4
Commercial Rolled Zinc 99 Zn, 0.08 Pb	20 to 40	32.5(b)
	20 to 40	23.(c)
Commercial Rolled Zinc 0.06 Pb, 0.06 Cd	20 to 40	32.5(b)
	20 to 40	23.(c)
Commercial Rolled Zinc 0.3 Pb, 0.3 Cd	20 to 98	33.9(b)
	20 to 98	23.4(c)

Miscellaneous Pure Metals

Metal	Temperature, deg Cent	Coefficient of Expansion per deg Cent
Cadmium	20	29.8
Chromium	20	6.2
Cobalt	20 to 100	12.3
Gold	20	14.2
Molybdenum	25 to 100	4.9
Silver	0 to 100	19.7
Tungsten	20	4.3

(a) For compositions of copper alloys, see page 24. (b) With the grain. (c) Across the grain. (d) Approximately the same for all commercial magnesium alloys.

ASM Metals Handbook v.19 p. 969
ASM Int'l 1st Ed. 1996

Material: Carbon steels (AISI)

			UTS	TYS	σ_f	% RA
1005		Hot-rolled	321 MPA*	225 MPA*	784 MPA*	73*
		Hot-rolled	355	236	1031	81
		Hot-rolled	358	266	951	70
1006	85 HB	Hot-rolled	318	248		73
	85 HB	Hot-rolled	318	248		73
	85 HB	Hot-rolled	318	248 (36Ksi)		73
1008	82/99 HB	Hot-rolled	363	253	808	77
1015	80 HB	Normalized	415	227	725	68
1018	106 HB	QT	354	250		
	118 HB	QT	496	290	678	
	209 HB	Hot-rolled	696	572	741	
1020	108 HB	Annealed	392	254	661	64
	105/109 HB	Hot-rolled	441	260	713	61
1025		Hot-rolled	547	306	1193	62
		Hot-rolled	566	387	880	57
1030	128 HB	Hot-rolled	454	289	764	59
	128 HB	Hot-rolled	454	289	764	59
1035		Hot-rolled	476	250	751	56

* UTS - ultimate tensile strength MPA ÷ 6.9 = Ksi (1000psi)
TYS - tensile yield strength: MPA ÷ 6.9 = Ksi (1000psi)
σ_f - fracture strength " " " "
% RA - Percent reduction in area before fracture of tensile test sample.

Table 2 Minimum tensile properties of selected aluminum casting alloys

Alloy	Strength class	Tensile properties: Ultimate tensile strength, MPa	Tensile properties: Ultimate tensile strength, ksi (1000psi)	Tensile properties: Tensile yield strength, MPa	Tensile properties: Tensile yield strength, ksi (1000psi)	Elongation, %
A356-T6(a)	1	262	38.0	193	28.0	5
	2	275	40.0	206	30.0	3
A357-T6(a)	1	310	45.0	241	35.0	3
	2	345	50.0	275	40.0	5
D357-T6(b)	Nondesignated	310	45	248	36	2
	Designated	345	50	275	40	3
A201-T7(a)	1	413	60.0	345	50.0	3
	2	415	60.0	345	50.0	5
B201-T7(c)	Nondesignated	385	56	330	48	2
	Designated	413	60	345	50	3

a) Per MIL-A-21180. (b) Per AMS 4241. (c) Per AMS 4242

HSM Handbook v. 19
Fatigue & Fracture
p. 815

has been shown that the formation of certain oxide films frequently acts as a protection against wear.[16]

ASM Metals Handbook Reprint 1958 P. 220

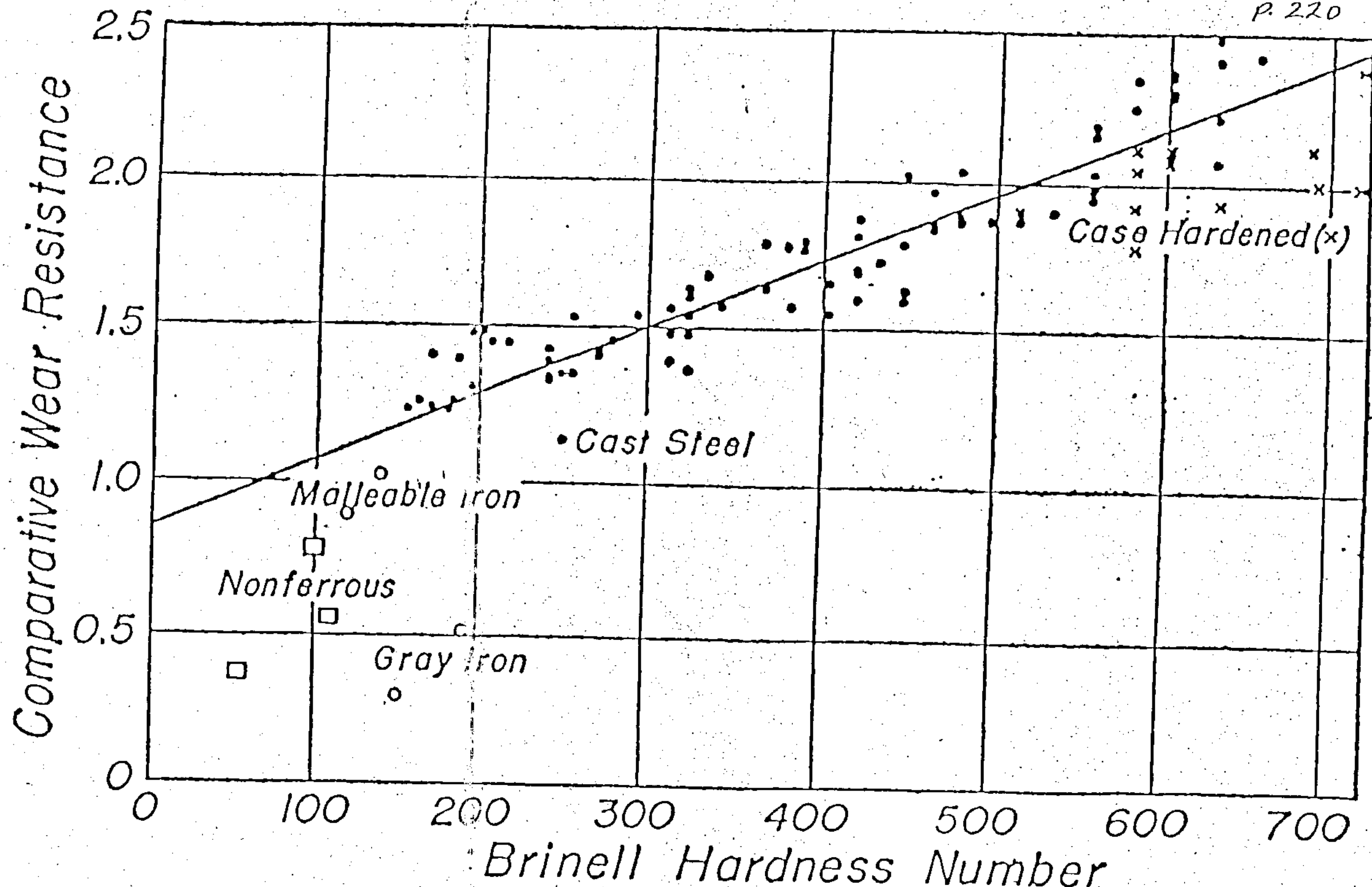

Fig. 2 General relation between hardness and abrasive wear of miscellaneous materials. Wet 80-mesh Crystolon abrasive on cast-iron lap. (Wear type IIA1.) Comparative wear resistance is the ratio of weight loss of specimen to weight loss of SAE 1010 steel (treatment not given). Unit pressures also not given. (From data by Weiss[23])